THE CLAIMS

What is Claimed Is:

1. A compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material having a surface roughness of less than 1 nm, wherein $0 < x < 1$.

2. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 1, wherein $x \leq 0.3$.

3. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 1, having a threading dislocation density $< 1 \times 10^5$ threading dislocation defects/cm^2 of surface area.

4. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 1, having a threading dislocation density $< 5 \times 10^4$ threading dislocation defects/cm^2 of surface area.

5. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 1, having a thickness in a range of from about 0.01 μm to about 3,000 μm.

6. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 1, wherein said surface roughness is ≤ 0.9 nm.

7. A compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ ($x \leq 0.3$) material with surface roughness less than 1 nm, and threading dislocation density $< 1 \times 10^5$ threading dislocation defects/cm^2 of surface area.

8. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 7, having a threading dislocation density $< 5 \times 10^4$ threading dislocation defects/cm^2 of surface area.

9. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 7, having a thickness in a range of from about 0.01 μm to about 3,000 μm.

10. The compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ material of claim 10, wherein said surface roughness is $\leq$ 0.9 nm.

11. An epitaxial heterostructure, comprising a compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer having a surface roughness of less than 1 nm, wherein $0 < x < 1$, and a heterostructural material deposited on the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer.

12. The epitaxial heterostructure of claim 11, wherein the heterostructural material comprises strained silicon.

13. The epitaxial heterostructure of claim 11, wherein the heterostructural material comprises a material selected from the group consisting of Si, Ge, GaAs, AlAs, AlGaAs, and related ternary and quaternary semiconductors.

14. The epitaxial heterostructure of claim 11, wherein $x \leq 0.3$.

15. The epitaxial heterostructure of claim 11, wherein the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer has a threading dislocation density $< 1 \times 10^5$ threading dislocation defects/cm^2 of surface area.

16. The epitaxial heterostructure of claim 11, wherein the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer has a threading dislocation density $< 5 \times 10^4$ threading dislocation defects/cm^2 of surface area.

17. The epitaxial heterostructure of claim 11, wherein the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer has a surface roughness less than 0.9 nm.

18. The epitaxial heterostructure of claim 11, further comprising a silicon on insulator (SOI) wafer.

19. The epitaxial heterostructure of claim 11, wherein the heterostructural material includes a cap layer of strained Si, overlying the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer, and a further cap layer of SiGe, overlying the cap layer of strained Si.

20. A compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer on a substrate formed by a process comprising contacting silicon and germanium precursor gases with the substrate under vapor deposition conditions comprising controlled temperature ramping, wherein the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ epitaxial layer has a surface roughness of less than 1 nm and a threading dislocation density less than 1×10^5 threading dislocation defects/cm^2 of surface area.

21. A method of forming on a substrate a compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ ($0 < x < 1$) epitaxial layer having a surface roughness of less than 1 nm, the method including contacting silicon and germanium precursors with the substrate under $Si_{1-x}Ge_x$ ($0 < x < 1$) epitaxial layer growth conditions, and varying temperature during at least part of said contacting.

22. The method of claim 21, wherein said step of varying temperature comprises temperature ramping.

23. The method of claim 22, wherein said temperature ramping is linear.

24. The method of claim 22, wherein said temperature ramping is non-linear.

25. The method of claim 22, wherein said temperature ramping is conducted in a temperature range of from about 900°C to about 700°C.

26. The method of claim 22, wherein said temperature ramping is conducted in a temperature range of from about 900°C to about 800°C.

27. The method of claim 21, wherein said step of varying temperature during at least part of said contacting, is conducted to yield the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ ($0 < x < 1$) epitaxial layer, having a threading dislocation density less than 1×10^5 threading dislocation defects/cm^2 of surface area.

28. The method of claim 21, wherein said step of varying temperature is conducted during part of said contacting, and said contacting further includes constant temperature $Si_{1-x}Ge_x$ ($0 < x < 1$) epitaxial layer growth conditions during another part thereof.

29. The method of claim 28, wherein said constant temperature is in a range of from about 775°C to about 825°C.

30. The method of claim 21, wherein the compositionally-graded, strain relaxed $Si_{1-x}Ge_x$ epitaxial layer comprises step or step graded $Si_{1-x}Ge_x$ structure.

31. The method of claim 21, wherein $x \leq 0.3$.

32. The method of claim 31, wherein the compositionally-graded, strain-relaxed $Si_{1-x}Ge_x$ ($0 < x < 1$) epitaxial layer, having a threading dislocation density less than 1×10^5 threading dislocation defects/cm^2 of surface area.

33. The method of claim 21, wherein said contacting step comprises chemical vapor deposition.

34. The method of claim 21, wherein said contacting step comprises reduced pressure chemical vapor deposition.

35. The method of claim 21, wherein said contacting step comprises ultra-high vacuum chemical vapor deposition.

36. The method of claim 21, wherein said contacting step comprises atmospheric pressure chemical vapor deposition.

37. The method of claim 21, wherein said contacting step comprises plasma-assisted chemical vapor deposition.

38. The method of claim 21, wherein said germanium precursor comprises a precursor species selected from the group consisting of germane (GeH_4) and halogermanes.

39. The method of claim 38, wherein said germanium precursor comprises a precursor species selected from the group consisting of chlorogermanes of the formula GeH_xCl_{4-x} wherein x is an integer having a value of from 1 to 3 inclusive.

40. The method of claim 21, wherein said silicon precursor comprises a precursor species selected from the group consisting of silane (SiH_4), Si_3H_8, Si_2H_6 and halosilanes.

41. The method of claim 40, wherein said silicon precursor comprises a precursor species selected from the group consisting of chlorosilanes of the formula SiH_xCl_{4-x} wherein x is an integer having a value of from 1 to 3 inclusive.

42. The method of claim 22, further comprising ramping said germanium precursor during at least a portion of said contacting step.

43. The method of claim 42, wherein said germanium precursor ramping is conducted concurrently with said temperature ramping during at least a portion of said temperature ramping.